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RADAR OBSERVATIONS OF VENUS IN THE SOVIET UNION DURING 1962

by

V. A. Kotel'nikov
V. M. Dubrovin
V. A. Dubinskiy
M. D. Kislik
....
A. M. Shakhovskoy

CONSULTANTS AND DESIGNERS INC
Arlington, Virginia
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RADAR OBSERVATIONS OF VENUS IN THE SOVIET UNION DURING 1962 * [Russian Title]*

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authors.
by V. A. Kotel'nikov
V. M. Dubrovin
B. A. Dubinskiy
M. D. Kislik and
....
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The conducting in 1962 of radar location of Planet Venus [1] by the Institute of Radio Engineering and Electronics alongside with a series of other organizations for the second time ** was already reported in the press. The same, but improved installation of 1961 was used, increasing its precision and reliability [3]. Owing to use at receiver input of a paramagnetic amplifier over a ruby crystal and to transmitter power increase, the sensitivity of the device was increased six-fold by comparison with 1961. The Doppler frequency shift of the reflected signal sue to Venus' and Earth's motion (taking account of rotation) was compensated by program design with the aid of a special device switching the receiver's heterodyne frequency by steps of 0.2 cps.

The frequency of the transmitted signal at every 4.096 sec was periodically changed by 62.5 cps so as to exclude the mean noise level in the received signal. The frequency spe trum of Venus-reflec-ed signals recorded on a magnetic tape, was investigated with the help of a 20-channel analyzer, similar to the one used for radar location of Venus in 1961 [3, 4].

The average spectrum for 20 sessions conducted from 20 October to 21 December 1962, constructed by the sum of measurements in both (**)

*[RADIOLOKATSIONNYYE NABLYUDENIYA VENERY V SOVETSKOM SOYUZE V 1962 GODU.]

** Each session consisted of transmission and reception, whose length was about equal to the time o signal propagation from Earth to Venus and return (4.5 — 7 min).

frequencies emitted by the transmitter, is plotted in Fig. 1 a. The analysis of the spectrum was conducted by filters with a 1 cps pass-band. The values of the tuning frequencies of the analyzer filters (f) relative to the frequency of the central filter (f_o) are plotted in the abscissa, and the quantity p, representing the ratio of reflected signal's power in the band of each filter, to that in the central filter band — in ordinates. The dotted line denotes the value of the mean-square error of measurements caused by noises. The spectrum of reflected signals may be approximated by the exponential (Fig. 1 a):

$$p = 0.37 \exp(-0.42 \quad f - f_o \quad). \qquad (1)$$

The central filter, in which the signal level is higher than that given by the formula (1), constitutes an exception.

The Venus' reflection factor* measured by the energy of the reflected signals in the 20 cps band during two months, varied within the (12 ÷ 18)% limits. The energy of reflected signals in the 1 cps band was 2.5 — 3 times less than the total energy.

The spectrum of the wideband component of reflected signals observed in 1961, was also invesigated in 1962. [2]. The transmitted signal consisted then of continuous periodical sendings whose frequencies differed by 2000 cps, and the duration — by 4.096 sec. One of the transmitter-emitted frequencies did not hit the range of frequencies of the receiver. The analyzer's filter pass-band constituted 100 cps during the investigation of the wideband component. Measurements of 1962 point to quite probable a presence of wideband component in the 300 cps band, with about the same intensity as in 1961.** Because of lesser number of sessions, as compared with 1961, during which the form of modulation of the transmitted signals allowed the investigation of the wideband component, the origin of the latter could not be reliably established.

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* Ratio of energy of received signals to that of signals which would have been received, if Venus were a smooth, ideally-conducting sphere.
** excluding measurements on 18 April 1961, when the intensity of the wideband component was somewhat higher than in other days of 1961.

A linear frequency modulation was applied for the measurement of the distance from Earth to Venus and the distribution of energy of the reflected signal by remoteness in 1962. The frequency of transmitter-emitted oscillations was periodically varying in a saw-tooth like manner by 4000 cps with a period of 1 024 sec. Owing to the application of a special circuit, a high linearity of frequency variation was attained.

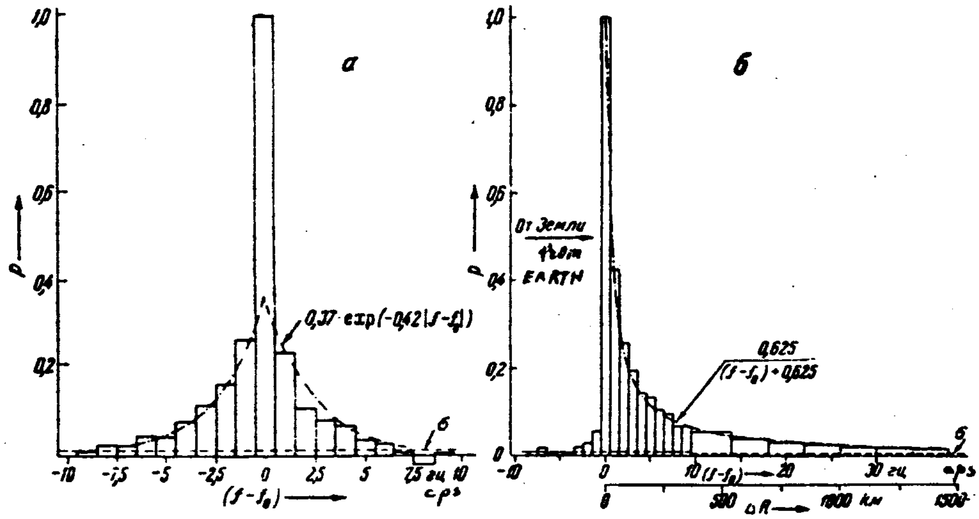

Fig. 1. - a — Average spectrum of reflected signals. 1 cps filter pass-band. б — Distribution by remotensss of the energy of Venus'-reflected signals with a frequency modulation. Filter pass-band of 1 and 4 cps.

Corrections were introduced in the modulation parameters so as to compensate the Doppler frequency shift caused by the motion of Venus and of the Earth. At reception the receiver's heterodyne frequency also varied in a saw tooth like fashion. At reception the beginning of modulation was set with a precision to 0.1 microsecond relative to the beginning of modulation at transmission by design program. If the former corresponded exactly to the factual time of signal arrival, the signal frequency at receiver output became higher or lower than the nominal. The correction to the computed time of signal propagation and the distribution of the energy of signals as a function of remoteness of the reflecting zone, were determined by the shift of spectrum of reflected signal and its parts.

The average spectrum of signals reflected from Venus with a frequency modulation according to 48 observation sessions conducted from 21 October to 21 December 1962 is plotted in Fig. 1б. Analysis was made with filters of 1 to 4 cps pass-band. The same quantities are plotted in ordinates of Fig. 1б as in 1 a. The spectrum shift by frequency, which could be caused by non-coincidence of the beginning of heterodyne modulation and the arrival of reflected signals was eliminated by "heterodynization" of the signal at reproducing magnetic recordings so that in each session the spectrum maximum get into the same filter.

Plotted also in the Fig. 1б is the remoteness axis ΔR with the idea that the spectrum maximum corresponds to the reflection of a Venus'point nearest the Earth, situated in the center of the visible part of the disk.

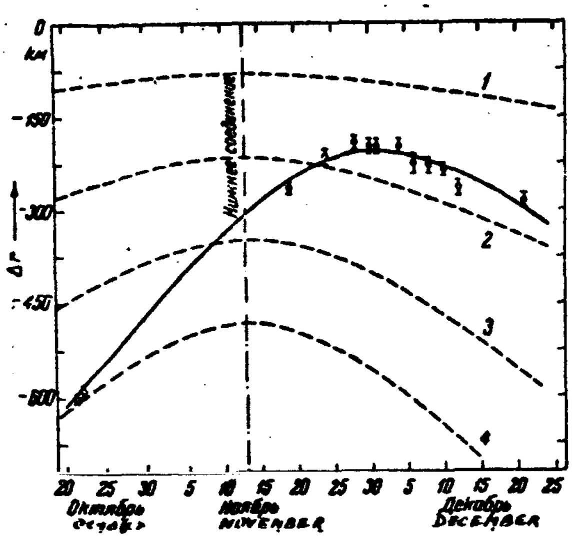

Fig. 2.- Variation of the distance between the Earth and Venus relative to the computed value.

1 — A = 149599000 km ;
2 — A = 149598500 km;
3 — A = 149598000 km;
4 — A = 149597500 km;

The reflection intensity decreases with the increase of the remoteness of the reflecting zone, while a noticeable reflection is still observed in zones, remote by 1500 km relative to planet's nearest point, whose diameter constitutes about two-thirds of that of Venus. Data of Fig. 1б can be approximated by the hyperbola (see Fig. 1б)

$$p = 0.625\,(f - f_0 + 0.625)^{-1} \qquad (2)$$

The rotation period of Venus was determined by comparing the computed spectrum width of the reflected signal obtained on the basis of Fig. 1б for different rotation periods, considering the structure of Venus' surface as isotropic, with a spectrum width obtained experimentally. The observed widening of the spectrum must have been caused for two reasons: — by Venus' own rotation, which is constant, and by apparent Venus overtaking by the Earth, depending upon their mutual position. The last component may be computed theoretically. The experimental results for the time from 20 October to 12 December 1962 show that if the axis of Venus' rotation is perpendicular to the ecliptic plane, reverse rotation (rotation opposite to the motion of Venus about the Sun) with a period of 200 ÷ 300 days is most likely.

The results of measurements of the distance between the Earth and Venus * by the lag of reflected signals with a frequency modulation are plotted in Fig. 2. Here Δr denotes the difference between the real and the computed values of the distance from a measuring point to the nearest point of Venus' surface. The values of mean-square errors of measurements are indicated in the Figure near every experimental point. In the unit measurement the mean-square value of the instrumentation error did not exceed 15 km.

In the computation of propagation time of reflected signals we admitted: — Astronomical Unit $=$ 149 599 300 km ; speed of light $=$ 299.792.5 km/sec; Radius of Venus $=$ 6100 km.

We indicated by dotted lines in the Figure how the quantity Δr would vary, were the real value of the Astronomical Unit equal to $A =$ 149 599 000, ... 149 597 500 km and — the ephemeride errors absent. At $A =$ 149 599 300 km, the results of measurements should coincide with the abscissa axis.

The experimental points graphically represented in the graph coincide with neither of the computed curves, which must be obtained if errors are contained in Earth's and Venus' ephemerides, according to which the computation of the propagation time is made. The smooth curve approximating the course of experimental points was obtained in the assumption that the value of the Astromomical Unit $A =$ 149 597 900 km, that the real position of the center of Venus is displaced by 270 km along the orbit by motion (by 0.5 angular seconds in the helicentrical system of coordinates) and the radius of Venus is by 80 km smaller than the value taken in the computation.

The difference between the A.U. obtained by us in 1961 and that produced above, constitutes 1400 km, which is within the limits of the admission (±2000 km) indicated for the 1961 measurements [2].

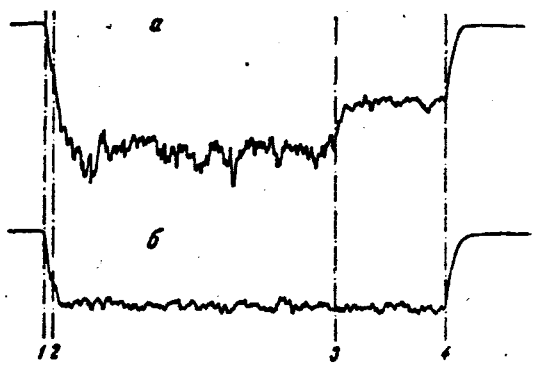

Fig. 3. Envelope of the Venus-reflected signal : a — channel with signal ; — channel without signal; 1 — switch of the receiver on; 2 — beginning of the reflected signal; 3 — end of the reflected signal; 4 — switching off the receiver.

If aside from the above-indicated variations of orbit parameters, others are made to vary too, the value of the A.U. may be somewhat different. The total processing of data will probably allow to allow, alongside with the A.U. to make more precise Venus' ephemerides also.

We plotted in Fig. 3 a the diagram of the envelope of the Venus-reflected signal obtained on 24 November 1962, when a non-modulating carrier was studied during 4.5 min. The pass-band of the receiving channel to detector (the latter being linear) constituted 6 cps and the time constant of the integrating circuit after detector was of 6 sec. For comparison we plotted in Fig. 3 б the digram of the noise envelope for a similar channel, shifted by 62.5 cps in frequency, in which there was no signal.

A sufficiently high signal to noise ratio, having taken place when Venus was near the Earth, gave us the idea to achieve a radio-telegraphic connection using Venus as a passive reflector. The words "МИР", "СССР", "ЛЕНИН" [respectively PEACE, USSR, LENIN] were transmitted in November 1962. We plotted in Fig. 4 the form of the word СССР which covered the total path of 85 million km.

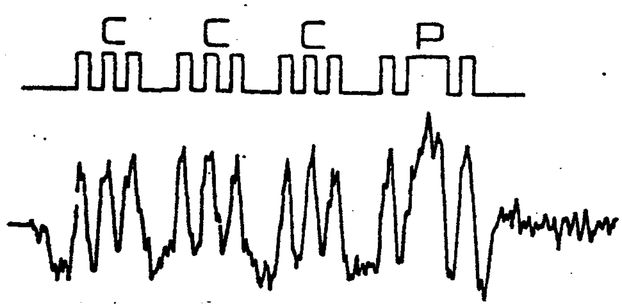

Fig. 4. - The word "CCCP" transmitted through Venus on 24 Nov. 1962.

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*** THE END ***

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